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Research Article

Design of NULLMAC Protocol for Mobile Ad Hoc Network Using Adaptive Antenna Array

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Usually, omnidirectional radiation pattern antenna is used in the mobile ad hoc network (MANET) which causes neighbor node interference, consumes more power, and supports only limited range of transmission. To overcome these problems, smart antennas are used. A lot of medium access control (MAC) protocols are proposed using smart antennas. Existing works addressed various problems such as hidden terminal problem, hidden beam problem, deafness of nodes, and head of line blocking problem. However, certain factors including determination of weight vector and conveying it to the neighbor nodes for distortion-free transmission are not considered. In this study, nullifying MAC (NULLMAC) framework is proposed using an adaptive antenna array (AAA) for improving network performance in MANET. NULLMAC framework uses channel information for achieving high throughput and spatial reuse through integrated physical and MAC layer. Before the transfer of data packets, the receiver initially determines its weight vector and conveys it to the transmitter through control packets. Then, the transmitter computes its weight to nullify the dynamic receivers present in the neighborhood region to find the desired receiver. Beamformer weights are determined through channel coefficients between a transmitter-receiver pair to establish distortion-free transmission. Extensive simulations are performed using OPNET integrated with MATLAB. NULLMAC framework achieves 27.22% more throughput and 40.46% increase in signal-to-noise ratio.

1. Introduction

In future communication systems, MANETs with its advancement in technology are going to play a vital role. It is possible to use numerous antennas at every node in a network. In point-to-point communication links, the utilization of several antennas has offered significant gain improvement in link capacity and also overcame various effects such as fading and multiuser interference. Antenna array integrated with nullifying medium access control (NULLMAC) protocol is established to achieve high throughput, reduce the interference to a greater level, and achieve efficient data communication [1].

The IEEE 802.11MAC makes use of DCF (distributed coordination function) as the basic MAC protocol considered for omnidirectional antenna in MANET. The technique named carrier sense multiple access with collision avoidance (CSMA/CA) is using handshaking mechanisms. In recent years, smart antennas are replacing omnidirectional antennas since they provide increased transmission range due to the presence of high gain antennas and thus providing more connectivity among the nodes. Signal transmissions occurring within the limited range can extend the battery lifetime and minimize the high-frequency radiations. The use of smart antenna helps to raise the network capacity through improved spatial reusage of wireless medium. Compared to omnidirectional antennas, this seems to be an attractive advantage while using directional antennas. In case of successful transmission scenarios while employing directional antennas, the node capacity shrivels to nil with increased number of nodes [2].

NULLMAC mechanism works both in line of sight and multipath scenarios. This protocol uses channel knowledge to preserve energy and spatial reuse with the help of nulling effect over ongoing communication sessions through adaptive antenna array (AAA). This module using AAA provides better integration of the physical and MAC layer resources and helps in optimizing the overall network performance.

The article is well-organized in a way that the literature survey was carried out in Section 2. In Section 3, discussion on adaptive antenna array mechanisms is performed. The proposed NULLMAC protocol is described in Section 4. In Section 5, the proposed protocol performance is presented. Conclusion of the study is presented in Section 6.

2. Associated Work

Many researchers have developed various MAC protocols to increase the spatial reusage. One of them is adaptive directional MAC (ADMAC) protocol supporting multiple simultaneous transmissions. The nodes lying in the transmission range of transmitter (TX) and receiver (RX) should be idle during the whole transmission. Thereby, the transmission rate gets reduced. With the help of antenna arrays, the problem of limited spatial reuse can be dealt.

Mahmud et al. [3] proposed the cooperation-based adaptive and reliable MAC designed for multichannel wireless networks uses both cooperation and directional multichannel cooperation methods. Directional multichannel deafness and hidden terminal problems are resolved using dual cooperation methods. Through parallel transmission, in the same data channel, using multidirectional packet transfer improves the utilization of effective channel bandwidth. Also, Global Positioning System-based neighbor discovery is performed.

Wang et al. [4] proposed the cooperative multichannel directional MAC (CMDMAC) protocol for directional ad hoc networks, which includes minorlobe interference. CMDMAC does not involve any extra tool or synchronization mechanism to deal with deafness and hidden terminal problems, since most of the existing MAC protocols require either of the type. The directional transmission adopts single data channel at many instances. CMDMAC provides significant networking performance in directional and multichannel transmissions.

Kulcu et al. [5] proposed a framework providing steerable smart antenna solutions for reliable and scalable wireless networks using IETF 6TiSCH protocol. The MAC layer and scheduling mechanisms used in the above protocol is integrated with minimal complexity smart antennas. The performance of 6TiSCH protocol in terms of data delivery is more in dense network traffic compared to existing protocol.

Verma et al. [6] proposed the switched beam antenna array MAC (SBAA-MAC) protocol with a fuzzy logic controller use switched beam antenna. An extra time gap, namely, additional control gap (ACG) is introduced amid control and data packets using fuzzy rules. Each node calculates its own unique value of ACG using the fuzzy logic approach based on the metrics obtained from the contending nodes through eavesdropping. ACG helps the neighbor nodes to exchange control packets and organize simultaneous data transmission. All nodes maintain a data structure called active neighbors table (ANT). Before the transmission of DATA packet, both transmitter and receiver must be familiar with each other's location for carrying out a successful transmission. This protocol involves an idle node to listen to the ongoing transmissions all over its antenna elements. Simultaneous transmissions are performed through directional request to send and directional clear to send (DRTS-DCTS) packets to all the nodes present in the network except active node. The results demonstrate that SNR and throughput in case of SBAA-MAC gets increased by 29.9% and 48.7%.

Wang and Huang [7] proposed S-MAC protocol for ad hoc networks with ESPAR antenna. The SDMA system allows multiple packet reception from spatially separated transmitters. The hidden terminal and other related problems can be solved using this protocol. S-MAC uses RTS and CTS frames (omnidirectional) to determine the position of a node. Beam-direction-to-send (BDTS), an omnidirectional control packet, provides communicating node's beam information to the neighbor nodes. All network nodes have beam table and update through control frame broadcasts to find busy beam direction and promoting effective communication. This scheme undergoes multiple transmissions, and hence, the network performance greatly expands the ability of the network, and it is mainly based on the SDMA mechanism. Modified omnidirectional network allocation vector (NAV) is shorter than the conventional NAV and allows nodes to identify whether the transmission medium status, and thereby, collisions can be prevented. On the other hand, the packet transmission time slightly rises with increase in packet size.

AMAC-MLSR framework proposed by Gang et al. [8] obtained minimized bit error rate and network delay. Here, each node is provided with an ESPAR antenna. One active element is surrounded by an array of passive elements. It places null in the direction of interfering signal and maxima in desired signal direction. The periodically collected neighbor information is maintained in the signal-angle table (SAT) which allows overlapping communication in different directions. It also helps in directional routing to find the best route for communication with neighbor nodes for transferring directional data and acknowledgment (ACK) packets through neighborhood link-state table (NLST). MLSR, modified link-state table, driven routing protocol collects the network status information at specific time intervals and updates in global link-state table (GLST). A node sends its

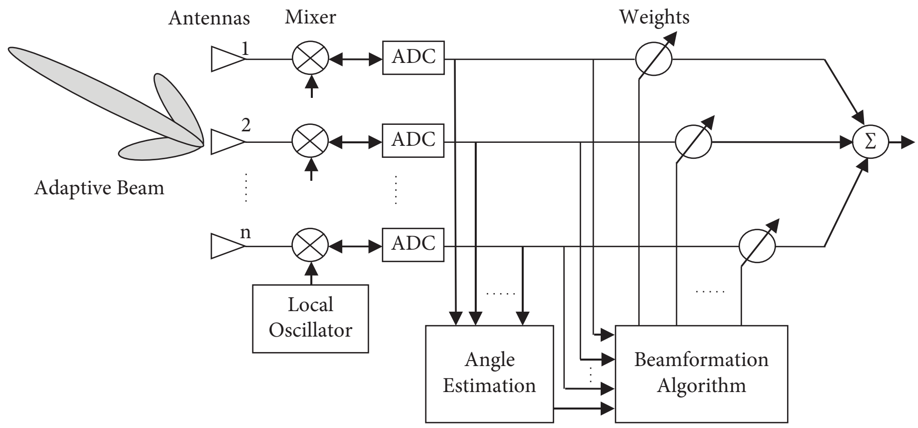

Figure 1: Adaptive antenna system.

topology-related information to one of its neighboring nodes at an intermittent interval based on least visited neighbor first algorithm for effective routing.

Lu et al. [9] proposed an ADMAC which has 4 portions: (1) carrier sensing mechanism with the collision avoidance method, (2) adaptive channel-access mechanism, (3) adaptive neighbor detection, and (4) neighbor node table updating. Nodes send their control packets in omnidirectional or directional manner. The main objective of the proposed method is to improve network throughput by enhancing simultaneous communication. However, this approach does not perform any channel estimation.

3. Adaptive Antenna Array Mechanism

The adaptive antenna arrays are provided with better signal processing algorithms for identifying the spatial signal signatures such as the direction of arrival of the signal (DOA) and find the beamforming vectors. Adaptive array antenna in comparison with switched beam antennas directs beam towards desired users and null towards interferers as they pass through a zone. To direct the array towards specific direction, the phases are to be selected properly. To nullify the interferer, a plane wave gets terminated reaching a particular direction by a null-directing beam former. Signal processors in adaptive antenna arrays can automatically adjust the variable antenna weights for obtaining improved signal-to-noise ratio.

Figure 1 shows the block diagram of the adaptive antenna array system and its signal processing unit. An adaptive antenna system depicting a main lobe orienting towards a user and directing nulls towards interferers.

NULLMAC makes use of MIMO channel knowledge to allocate antenna weights that nulls current communication sessions. This enables more simultaneous communication to take place. Channel bandwidth is divided into two logical channels which are orthogonal to each other. One channel is allocated for control message transfer [10]. The other one is for data and acknowledgment packets transfer. Multiple access schemes, namely, FDMA (frequency domain) or CDMA (space domain) can be incorporated. The channels are assumed to be symmetric where the channel parameters from the transmitter node to the receiver node and vice versa are the same. This assumption is found to be valid when the up and down link frequencies are similar. This protocol can be used for channels using feedback for allocating coefficient values. But for asymmetric channels, the header details tend to increase.

The channel model considered here is the narrowband channel model, where bandwidth of the link is less than the channel bandwidth. It enables NULLMAC to evaluate the data channel coefficients using pilot signal. If the channel is not considered to be narrowband, then NULLMAC is modified in such a way as to estimate the data channel coefficients with the help of orthogonal frequency division multiplexing at the physical layer [11, 12]. The data and control channels are implemented as sets of subcarriers with no overlapping.

Active neighbors-nullifying (ANN) algorithm is used to measure the weight vectors for every node pair that needs to communicate with known channel characteristics. The MIMO channel where 4 antennas are used both ends is described in Figure 2 [13].

(1) $s(t)$, modulated signal is sent through a transmit beam former
(2) $s(t)$ with weights w_{Ti} is sent through each antenna
(3) The signals with weights w_{Ri} at the receiver are summed to obtain $r(t)$ which is the receive beamformer output
(4) $r(t)$ is detected and the original bit stream is obtained

Consider a node with N antennas, say $M = N$. Let w_T $(N^* 1)$ vector of transmit weights and w_R $(N^* 1)$ vector of receive weights. The following equation shows the received signal at the i^{th} antenna:

$$x_i(t) = s(t) \sum_{j=1}^{N} w_{Tj} h_{ji}. \quad (1)$$

The received signal output $r(t)$ is given by the following expression:

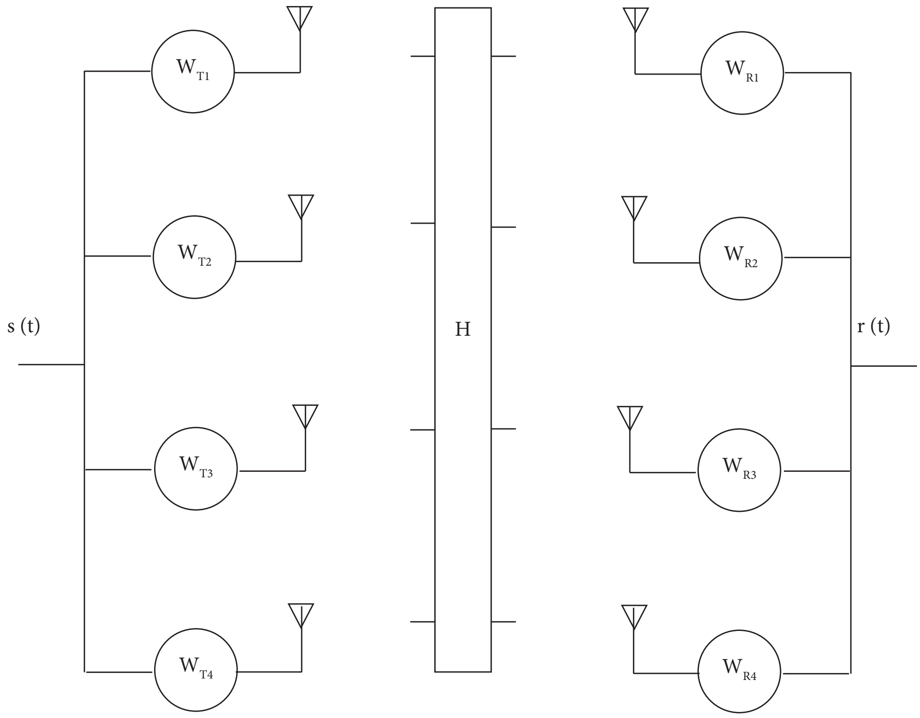

Figure 2: MIMO system with 4 antennas.

$$r(t) = \sum_{i=1}^{N} w_{Ri} x_i(t). \tag{2}$$

Hence, $r(t) = s(t) w_T^T H w_R$. The complex gain value of $s(t)$ after transmit beamforming, and the channel and receive beam forming is given as $w_T^T H w_R$. Choosing the appropriate transmitter and receiver weights, whether the signals are properly received or nulled can be ensured. In general, either w_T or w_R will be a known value and the other value has to be found [14].

ANN algorithm considers three cases to determine the desired communication pair are given as follows:

(i) If the transmitter and the receiver are considered to be the desired communication pair with fixed w_R, w_T is found using $w_T^T(Hw_R) = 1$.

(ii) If the receiver is busy in another communication with fixed w_R, w_T is found using $w_T^T(Hw_R) = 0$.

(iii) If the transmitter is busy in another communication with fixed w_T, the receiver with w_R is found using $(w_T^T(H)\, w_R = 0$.

3.1. Design of Adaptive Antenna Weight. Let H_{lm} be the channel matrix with l[st] node being the transmitter and m^{th} node being the receiver. Consider the first node can accept a packet from node 2 without interference from nodes $3, 4, \ldots, P + 2$, which are presently engaged in transmission to other nodes with weights w_{Tk}. The steps to calculate the receive beamformer design are as follows:

(i) Calculate the essential channel vectors to transmitters, $h_k^T = w_{Tk}^T H_{K1}$, where $k = 3, 4, \ldots, P + 2$.

(ii) Calculate the required transmitter's effective channel vector, $h_2^T = w_{T2}^T H_{21}$. w_{T2} will be calculated using $w_{T2} = (1/\sqrt{N})[1\,1 \ldots 1]^T$.

(iii) Then, form N by $P+1$ matrix of channel vectors $X = [h_2 h_3 h_4 \cdot \cdot \cdot h_{P+2}]$

(iv) Find $\hat{w_{R1}}$ so that $X^T \hat{w_{R1}} = \text{c}$, where $= [1\,0 \ldots 0]^T$ providing unity gain value to the required transmitter and null gain to the remaining transmitting nodes.

(v) Then, scale up $\hat{w_{R1}}$ using the formula $w_{R1} = (\hat{w}_{R1}^T \hat{w}_{R1}^*)^{-1/2} \hat{w}_{R1}^*$ for attaining unit normal receiver weight vector.

The receiver at node 1 is capable of nulling at most other $N - 1$ transmitters. The scaling operation makes sure that the transmitter is capable of attaining the required signal-to-noise ratio ($|w_R^T w_R^*|^2$). Also, it is found that receiver gain cannot raise the SNR value because receiver gain has the same impact over both signal and noise [15–18].

Consider node 1 to 2 transmission without creating any interference to nodes $3, 4, \ldots, P + 2$. They are assumed to be engaged in some transmission with receive weights w_{Rk}, $k = 3, 4, \ldots, P + 2$. The steps to calculate transmit beamformer design are as follows:

(i) Calculate effective channel vectors to remaining receivers:$h_m = H_{1k} w_{Rk}$, where $k = 3, 4, \ldots, P + 2$.

(ii) Calculate required receiver's effective channel vector, $h_2^R = w_{R2}^R H_{12}$. Also, consider that w_{R2}^R is designed already with the help of the beamformer design at the receiver steps as discussed above.

(iii) Then, form N by $P + 1$ matrix of channel vectors say $X = [h_2 h_3 h_4 \cdot \cdot \cdot h_{P+2}]$

(iv) Determine wT1 so that $X^T w_{T1} = z$, $z = [1\ 0\ \cdots 0\ ]^T$ resulting in attaining unity gain value from nodes 1 to 2 and null gain value to remaining receivers.

Scaling the transmitter weights by a constant value, the required SNR at receiver side may be obtained. Similar to beamformer design at receiver, transmitter at node 1 is capable of directing nulls to the maximum of $N-1$ receivers. The necessary transmit power needed to obtain unity signal strength in receiver node matches $w_T^T w_T^*$. The estimation of channel coefficients is done, while the control messages start exchanging just before the advent of data packet transmission. The transmission channel is approximately considered to be constant during control and data packet transmissions [19].

4. The NULLMAC Protocol

The NULLMAC protocol designed for the adaptive array antenna is responsible for spreading the weight vector information of all the active nodes through control packets. Before the transfer of data packets between transmitter and receiver, the receiver initially determines its weight vector in order to nullify the intrusions available in the neighborhood with the help of the methods discussed before. Receiver weights are determined and are informed to the nodes at the transmitter region [20]. Then, transmitter computes its weight to nullify the active and dynamic receivers present in the neighborhood region in order to attain unity gain value to the preferred receiver. Finally, both transmitter and receiver inform neighbor nodes about the weight vector selection details.

NULLMAC considers the total bandwidth (BW) available in two channels, namely, data channel (DC) and control channel (CC), which are orthogonal to each other through FDMA or CDMA. The two orthogonal channels enable every node to easily track other ongoing communications taking place in the neighboring nodes. The allocated bandwidth to CC is represented as αBW, where α lies between 0 and 1. This parameter depends on the network topology and the available degrees of freedom. The two physical properties considered in NULLMAC are given as follows:

(i) A node is capable of receiving packets on both DC and CC simultaneously

(ii) During transmission over any of the channels, the node is unable to receive a packet on another channel

The NULLMAC protocol makes use of the CSMA/CA technique over CC in order to access a DC. Mostly, collisions will not tend to occur on DC. If node A has to pass data to node B, then DC can be accessed with the help of three control packets, namely, RTS, CTS, and data send (DS). Node A sends RTS packet (including w_R for receiving the CTS packet) to node B on CC. If node B is idle, it responds with CTS (including w_R for getting data packet and w_T for transmitting ACK) to node A on CC. Node A sends DS packet (including w_T for transmitting the data packet and w_R for receiving the ACK) to node B over CC. When DS transmission is completed, data are transmitted on DC. After completion, the receiver sends ACK packet over DC. The concept of timeouts is used in order to recover from unexpected situation. If a timeout occurs, then the current exchange process gets cancelled, and it is repeated some time later. Adaptive antenna weights are included in control packets, and they are conveyed to their neighbor nodes [21].

Only omnidirectional transmissions occur over the CC with constant power. The pilot segment of control packet exchange uses all antennas. An omnidirectional or multiple antennas are used by the message component of control packets. Simple space-time coding methods are used in RTS/CTS/DS exchanges. If refined space and time schemes are used for control packet transmissions, then the omnidirectional transmissions over CC are easily possible in a deep fade environment. Modifications can be done over the NULLMAC protocol to work on cases such as large delay spread through advanced signal processing techniques [22].

The modified RTS, CTS, and DS frame formats used in NULLMAC with weight vector information are denoted in Table 1.

Consider a network scenario as in Figure 3 with 6 nodes from A to F. The dotted lines represent the node pairs being within the transmission range of one another. Consider a case that nodes C and E transmit data packets to D and F nodes, respectively, at certain instant of time. Nodes A and B are idle, and node A wish to transmit a packet to B. Node A usually cannot make transmissions to node B, since it may collide with packets received at nodes D and F.

If node A has four adaptive antennas, then it sets zero gain value in the directions of nodes C, D, and F to avoid collision with current communications. In the same way, node B has the ability to nullify the interference effect created by D, E, and F nodes while node A is getting a packet as in Figure 4.

Also note that transmission from node F must be nullified in order to overcome the interference, when node F sends acknowledgment for receiving the packet from E. Node A must nullify node C in such a way that it can have the reception of ACK packet from node B with no interference. Node A/B must check ongoing transmissions between C/D (E/F). It must also verify whether F/D is occupied in any other link. Node A/B must be aware of antenna weight metrics used by the nodes C, D, and F/D, E, and F. Node A/B must be aware of antenna weight metrics used by node B/A to receive the data/ACK packet. Node A/B must know the channel coefficient matrices of the nodes C, D and F/D, E and F.

Nodes A and B tend to know the communication happening in their neighborhoods by carefully watching CC in NULLMAC. Consider a case in which, before the commencement of data transmission between C and D, the node D will direct a CTS packet in response to RTS packet sent by node C. The node C will reply to CTS packet with DS packet. Now, node A overhears the transmissions between C and D, if it is not involved in any transmission at that instant of time. In the same way, node A listens to the CTS packet from node F but it does not listen to DS packet from node E. Thus,

Table 1: The modified RTS, CTS, and DS frame formats.

Packet control	Time slot	Receiver location	Transmitter location	Weight, W_R	FCS
(a) RTS frame format in bytes					
2	2	4	4	4	4
Packet control	Time slot	Receiver location	Weight W_R	Weight W_T	FCS
(b) CTS frame format in bytes					
2	2	4	4	4	4
(c) DS frame format in bytes					
2	2	4	4	4	4

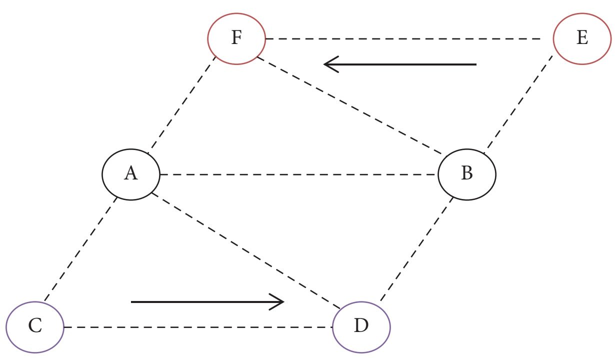

Figure 3: NULLMAC scenario.

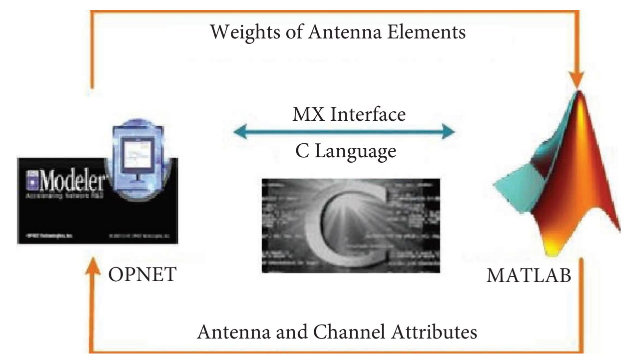

Figure 5: Interfacing OPNET and MATLAB.

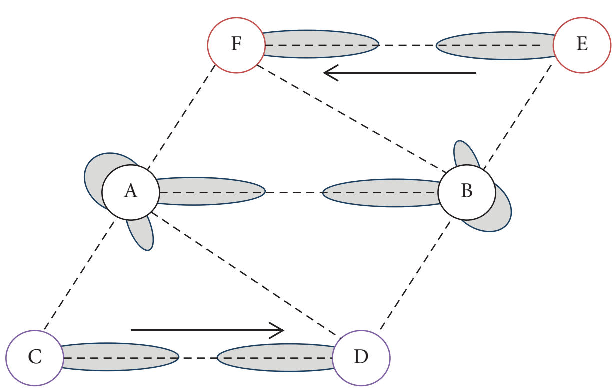

Figure 4: Adaptive beamforming.

node A determines that the nodes C, D, and F are available in its neighborhood and are participating in some other communication. A node is unable to hear CTS or DS packet during transmission. Hence, node E is unaware of recent transmission between A and B that will start after the packet transfer to node F. When a node transmits data packets with lack of the knowledge about the ongoing transmissions, then the corruption occurs during the reception of a packet. To avoid this problem, all nodes must be made to wait for a certain time period before initiating another transmission.

The merits of directional transmission over the control channel have been discussed and require either the channel (directions) knowledge to all its neighbors which may occur in nonmobile scenarios or using omnidirectional packet transmissions for channel estimation and determining the neighbor nodes. NULLMAC is mainly for the networks which involves movement of nodes. The estimation of channel and neighbor discovery takes place for every packet [23, 24]. There is no assumption of the availability of prior channel (directional) information for the intended message recipients and the neighboring nodes which may later involve in the next communication process.

The nodes must have the knowledge regarding the H matrix to the neighboring nodes. The method used for measuring channel coefficients is by including the pilot signals within RTS and CTS packets. Nodes, on hearing control message, measure the corresponding channel coefficients and store it. Both channels with similar channel coefficients are found to be reciprocal to each other and have constant coefficients during transmission over DC [25–27].

5. Simulation Results

The simulation is carried out using the OPNET modeler (the discrete event simulator) for evaluating the network performance characterization. The MATLAB code is integrated into the antenna model to permit reusage of adaptive antenna nulls and implementing various kinds of beam forming algorithms. Analysis is purely based on the performance and the effects happened on various upper layers especially the network and data link layers. The MATLAB avails MX interface for interfacing OPNET and MATLAB, which allows C programs to call functions developed in MATLAB as shown in Figure 5.

NULLMAC allows OPNET and the MATLAB to process simultaneously and information exchange takes place during execution. OPNET implementation has two channels: control channel (CC) and data channel (DC). The packet transmissions taking place in CC are made available to all network nodes within transmission range. Nodes receive omnidirectional control messages when lies within this range. Nulls can

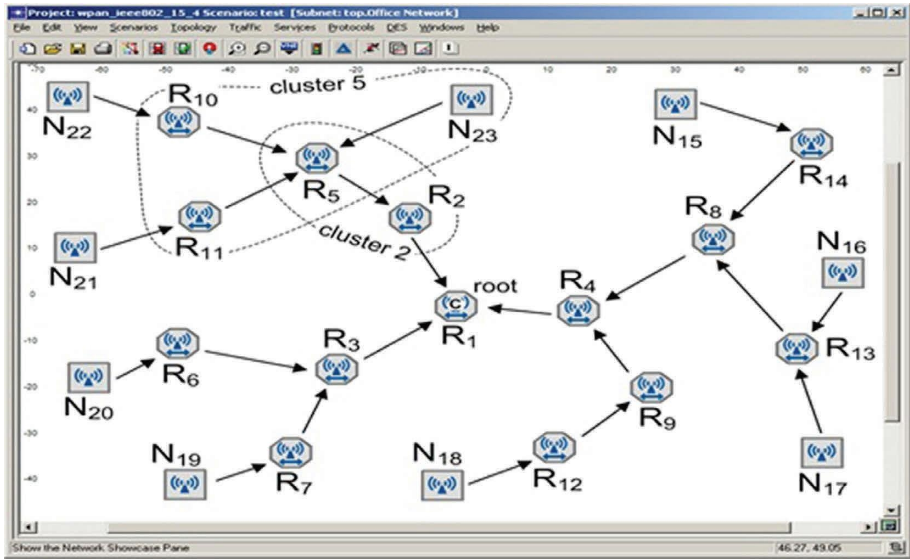

FIGURE 6: Project: MANET project test [subnet : top.office network].

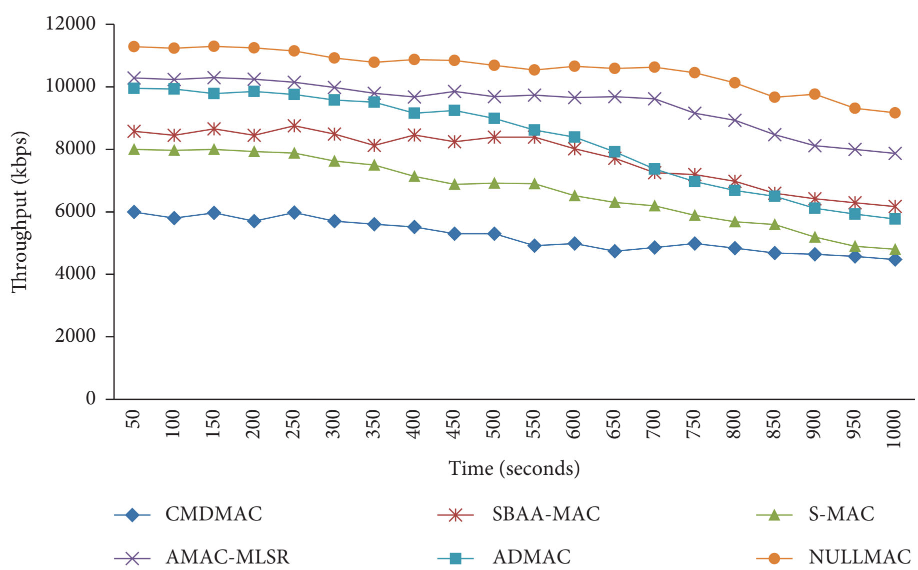

FIGURE 7: Comparison of throughput.

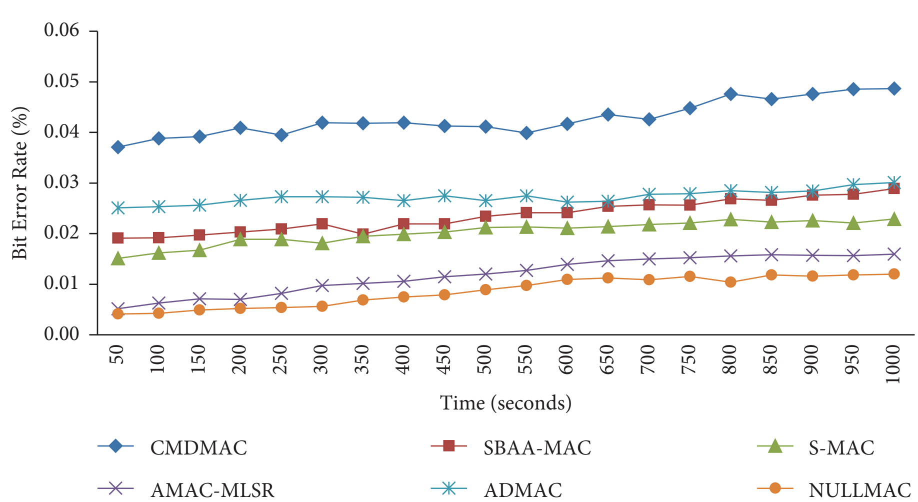

FIGURE 8: Comparison of bit error rate.

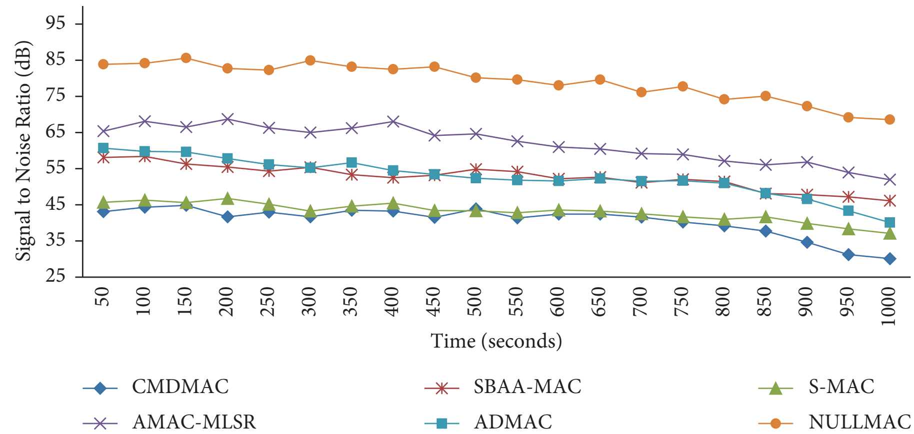

Figure 9: Comparison of signal-to-noise ratio.

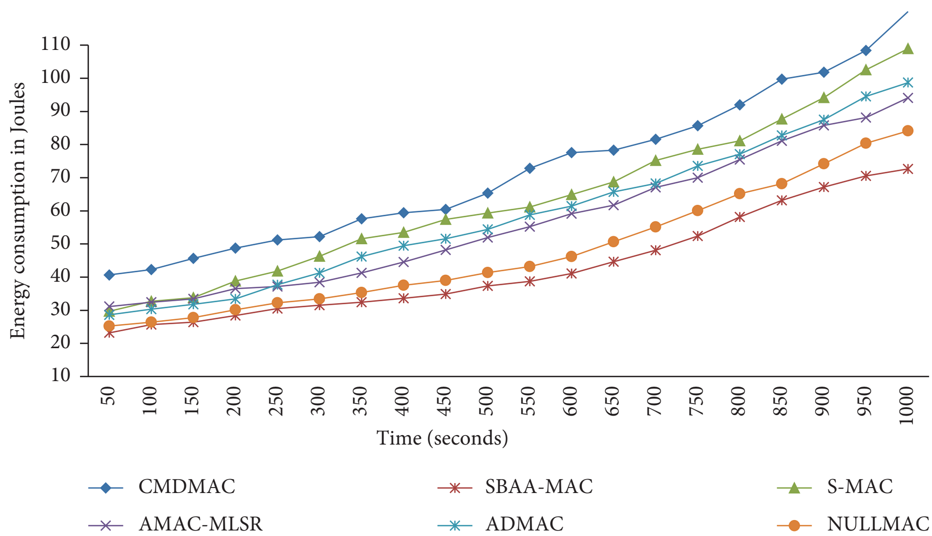

Figure 10: Comparison of energy consumption.

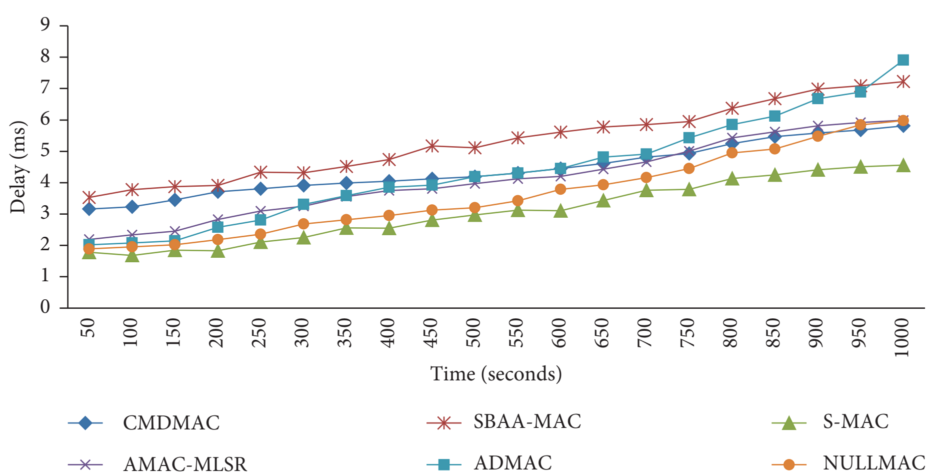

Figure 11: Comparison of delay.

also be sent in a communication scenario. Nodes failing to receive the control packets are considered to be "out of range." These nodes have poor knowledge about the ongoing communication. Hence, they may cause collisions.

Carrier sensing is carried over on DC and CC before the start of communication to avoid collisions. The channel state information and weight vectors are registered in MATLAB. The events taking place in OPNET is transported to MATLAB for regular state updates. Receiver SNR, transmitter power measurements, and beamformer design are realized in MATLAB and then to OPNET. From numerical feedback, succeeding strategy in agreement with the NULLMAC disclaimers is carried over. The simulation results of NULLMAC relative to ADMAC are as follows.

5.1. Performance Analysis. Simulations were conducted for the proposed NULLMAC frameworks. The factors like throughput, signal-to-noise ratio, bit error rate, delay, and energy consumption were considered. These parameters of NULLMAC are taken for comparison among the existing methods, namely, CMDMAC, SBAA-MAC, S-MAC, AMAC-MLSR, and ADMAC.

Figure 6 shows the OPNET simulation screenshot for node formation and interfaced with MATLAB. Simulations are conducted for the proposed NULLMAC frameworks with certain existing methods. The parameters such as throughput, bit error rate, signal-to-noise ratio, energy consumption, and delay are considered for simulation. These parameters are measured to determine the quality of service and the overall network performance.

5.1.1. Comparison of Throughput. Throughput is defined as the rate at which the data packets are successfully sent on a transmission channel. It is measured in bits per second (bps).

It is observed from Figure 7 that the throughput obtained in NULLMAC is 27.22% more compared with the average values of existing methods CMDMAC, SBAA-MAC, S-MAC, AMAC-MLSR, and ADMAC. On the whole, the throughput obtained in NULLMAC seems to be high compared to all the other methods. The throughput gets increased due to the efficient utilization of the bandwidth and null interference.

5.1.2. Comparison of Bit Error Rate. The bit error rate is the rate at which the bits are in error. In other words, BER is also stated as the number of error bits to total bits transmitted within a time duration. It is a unit less factor, and it is often expressed in percentage.

It is observed from Figure 8 that the BER of NULLMAC is 45.97% less compared with average values of existing methods CMDMAC, SBAA-MAC, S-MAC, AMAC-MLSR, and ADMAC. On the whole, the BER of NULLMAC seems to be very less compared to other methods. The error rate seems to be very less in NULLMAC since weight vectors are conveyed to the neighbor nodes to transmit data only to the desired receiver, thereby eliminating the interference and providing distortion-free communication.

5.1.3. Comparison of Signal-to-Noise Ratio. SNR is the ratio of the average information signal power to the accumulated average power of all interference and noise sources. It is usually expressed in dB.

From Figure 9, the SNR obtained in NULLMAC is 40.46% more compared to average values of existing methods CMDMAC, SBAA-MAC, S-MAC, AMAC-MLSR, and ADMAC. On the whole, NULLMAC shows good performance in terms of SNR compared to other methods. The SNR in NULLMAC is more since maximum power is radiated towards the desired user direction using adaptive antenna.

5.1.4. Comparison of Energy Consumption. Energy consumption during message distribution is the ratio of energy spent by a mobile node with respect to the overall energy of a network.

Figure 10 describes the energy consumption in NULLMAC gets decreased by 13.43% compared with the average values of existing methods CMDMAC, AMAC-MLSR, S-MAC, and ADMAC. But the energy consumption in SBAA-MAC is 8.1% less compared to NULLMAC protocol. The energy savings are more in NULLMAC since all the available degrees of freedom are not used for nulling which further reduces transmission energy.

5.1.5. Comparison of Delay. The network delay denotes the time required for a data bit to travel from the source to the destination in a network. It is usually measured in fractions of seconds.

Figure 11 describes the delay in the proposed method NULLMAC gets increased by 14.96% than that of the existing method S-MAC. Delay in NULLMAC seems to be less compared to other existing methods CMDMAC, SBAA-MAC, and ADMAC. On the whole, the delay in S-MAC seems to be very less compared with all the other methods. The NULLMAC takes more time due to the determination of antenna weight vector and conveying it to the neighbor nodes. The delay in NULLMAC protocol has not reduced much than the existing methods due to excess time required to transmit and receive beamformer weight determination.

6. Conclusion

In wireless communication, the principal motive for rising interest in smart antenna systems is network capacity increase, reduction of interference, and low power consumption. The principles of smart antenna technology and conventional ad hoc network protocol have been analysed. Medium access control techniques using smart antenna remain as an active area of research with horizons to be explored. Unlike most of the existing works, this method is designed for nodes in a network having multipath propagation. It routes nulls to all other nodes except the desired node for allowing parallel data transmissions in its neighborhood. The beamformer weights are designed and implemented for directing the nulls. The NULLMAC protocol is designed for narrow band channel models and can be extended for wideband scenarios. The implementation of OPNET integrated with MATLAB is used for performing simulation. Performance analysis shows that NULLMAC yields 27.22% increased throughput, 40.46% increased SNR, and reduced BER of about 45.97%. The only drawback of NULLMAC is that the energy consumption gets increased by 8.1% compared to AMAC-MLSR and delay gets increased by 14.96% compared to S-MAC. However, NULLMAC shows better performance in terms of throughput, SNR, and BER compared to other existing protocols.

Data Availability

The data used to support the findings of this study are available from the first author upon request [Mahendrakumar Subramaniam, email id: Mahendrakumar.sp@gmail.com].

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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